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It's All In The Genes: Landmark Research Shows Genetic Link To Community Makeup And Ecosystem Evolution

It's common knowledge that genes control traits such as eye and hair color. But a large group of scientists from two continents has found that the genes of one organism not only control the characteristics of that individual but also dictate the behavior of thousands of other organisms in a community.

They say these genes, in fact, influence the evolution of an entire ecosystem.

"We're pushing a whole new field of research," said lead investigator Tom Whitham, Regents Professor of biological sciences at Northern Arizona University.

It's a field that has not been explored before. After all, the idea of looking at the genes of thousands of species in even a simple community is daunting at best.

"What we've done is zero in on a foundation species, because not all species are as equally important ecologically," Whitham said. The foundation, or key, species in this case is the cottonwood tree, which is the first tree to have all its genes sequenced, or mapped.

Among the genes under study are those that control the level of tannins in cottonwoods, which are dominant trees in riparian habitats in the West. Different individuals, or genotypes, of cottonwoods have different levels of tannins.

These genetically controlled tannin levels drive the structure--or phenotype--of a riparian forest, according to Whitham. Tannins affect the decomposition rate of cottonwood leaves, which in turn affects the fertility of soils, which affects the microbes in the soil, which affect the insects that live in the soil or eat the leaves, which affect the birds that feed on the insects, and so on.

In the July issue of Nature Reviews Genetics and the May issue of Evolution, Whitham and fellow researchers discuss how this phenotype is heritable on an ecosystem level. That is, the progeny of a tree are likely to support the same communities of organisms and ecosystem processes that their parents supported.

It's a premise with far-reaching implications. Consider, for example, conservation efforts to preserve biodiversity in the face of habitat destruction, climate change and other impacts on the environment. Planting trees that are genetically diverse will result in increased diversity of other species in the dependent community. The greater the tree diversity, the greater the chance of associated species surviving environmental degradation.

"It's not enough to save rare and endangered species. We need to save genetic diversity in the foundation species," said Jennifer Schweitzer, a co-author of the Nature Reviews Genetics paper and postdoctoral researcher at NAU. "Having high genetic diversity in these foundation species is insurance against changes in the future."

The research also has ramifications when it comes to genetically modified organisms and their effects on the landscapes in which they are introduced. For example, grasses that are genetically altered to prevent weed growth could pass that resistance along to exotic plants, which then might take over a community and change the evolution of that ecosystem.

More than 50 researchers from the United States, Canada and Australia are studying this genetic driver of community structure and ecosystem evolution. The work is funded by a $5 million Frontiers in Integrative Biological Research grant

from the National Science Foundation. The project includes scientists from a multitude of disciplines because, as Whitham says, "No one person has all the skills to do this."

"This is an exciting project with global impact, drawing on the expertise of geneticists, ecologists, molecular biologists, biogeographers and others," said Chris Greer, program director at the National Science Foundation. "The results are expected to not only shed light on how complex biological communities function but to inform efforts to address the impact of human activities, such as landscape fragmentation, on stressed ecosystems across the planet."

The researchers are the first to study the genetic framework of communities and ecosystems in the wild. They have planted several experimental "common gardens" of cottonwoods in Arizona and Utah. The trees are propagated at NAU's research greenhouse. Through DNA fingerprinting, the scientists know the precise genetic makeup of each tree.

In one experiment, Whitham's group worked with the Bureau of Reclamation to plant about 10,000 trees at the Cibola National Wildlife Refuge along the lower Colorado River, about 20 miles south of Blythe, Calif., to examine how genetic diversity at the stand level influences communities and ecosystem processes.

"The Bureau of Reclamation gets restoration out of this project, and we get this incredible experiment," said Whitham.

All of the experiments, so far, have exceeded the researchers' expectations. "Initially we thought that the [genetic influences] would be more localized--that the influences would be less genetic and more environmental as we moved beyond the local common garden setting to all of the western U.S." In the end, however, Whitham said, "Plant genes are far more important than we ever expected them to be."

Now the researchers want to know if their findings hold true in different environments around the world. "To understand how important something is, you have to test in multiple locations," Whitham said.

A parallel study in Australia that examines the eucalyptus tree as the foundation species is yielding the same results as the studies on cottonwoods. And Whitham has just returned from South Africa and Borneo in Southeast Asia, where he is planting the seeds for further study.